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Evaluation of the HSA (High Surface Area) Reactor for Metal Recovery and Cyanide Oxidation in Metal Plating Operations

Centec Corp., Reston, VA

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EVALUATION OF THE HSA REACTOR FOR METAL RECOVERY AND CYANIDE OXIDATION IN METAL PLATING OPERATIONS

by

CENTEC Corporation
Reston, Virginia 22090

Contract No. 68-03-1721

Project Officer

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16. ABSTRACT

The electrochemical removal of heavy metals and cyanide from the wastewaters from electroplating shops is one alternative available to plating shops in achieving compliance with effluent regulations. Several of such systems manufactured by HSA Reactors, Ltd., have been installed since 1981 with varying degrees of success. This report is the result of a brief survey of the effectiveness of several of these installations.

Six installations of HSA electrochemical recovery system were tested to establish the performance that may be expected from the technology. Results showed a wide variation of performance, ranging from nearly ineffective to a metal removal and cyanide destruction capability sufficient to achieve compliance with effluent regulations. The tests indicate that the technology is a viable solution to the pollution control problem, when properly applied. Further the system permits compliance with effluent regulations while producing a recycleable product rather than a waste subject to regulation under RCRA, Subtitle C.

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FOREWORD

The U. S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water systems. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. The Clean Water Act, the Safe Drinking Water Act, and the Toxics Substances Control Act are three of the major congressional laws that provide the framework for restoring and maintaining the integrity of our Nation's water, for preserving and enhancing the water we drink, and for protecting the environment from toxic substances. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Water Engineering Laboratory is that component of EPA's research and development program concerned with preventing, treating, and managing municipal and industrial wastewater discharges; with establishing practices to control and remove contaminants from drinking water and to prevent its deterioration during storage and distribution; and with assessing the nature and controllability of releases of toxic substances to the air, water, and land from manufacturing processes and subsequent product use. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Chemical precipitation of heavy metals from electroplating wastewaters results in formation of a sludge waste which is classified as hazardous under Subtitle C of the Resource Conservation and Recovery Act. The HSA, or High Surface Area, Reactor is of interest because it removes metals from these wastewaters in a form which may prove suitable for recovery and recycle to the secondary metals market, or even direct recycle in the electroplating process. This report documents the findings of a brief evaluation of six installations of the HSA Reactor on a variety of electroplating lines.

ABSTRACT

The electrochemical removal of heavy metals and cyanide from the wastewaters from electroplating shops is one alternative available to plating shops in achieving compliance with effluent regulations. Several of such systems manufactured by HSA Reactors, Ltd., have been installed since 1981 with varying degrees of success. This report is the result of a brief survey of the effectiveness of several of these installations.

Six installations of HSA electrochemical recovery system were tested to establish the performance that may be expected from the technology. Results showed a wide variation of performance, ranging from nearly ineffective to a metal removal and cyanide destruction capability sufficient to achieve compliance with effluent regulations. The tests indicate that the technology is a viable solution to the pollution control problem, when properly applied. Further the system permits compliance with effluent regulations while producing a recycleable product rather than a waste subject to regulation under RCRA, Subtitle C.

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SECTION 1

INTRODUCTION

Regulations promulgated by the U.S. Environmental Protection Agency (EPA) govern the allowable pollutant content of discharges from industrial processes. The Metal Finishing industry is one of the major sources of heavy metal and cyanide pollution. The capital expenditures for equipment to remove these pollutants from wastewater and wastes impose a considerable economic burden on the industry. In addition, the disposal of metallic sludges produced by conventional waste treatment systems is becoming increasingly more difficult and costly. A system, such as the HSA reactor, which permits recovery and recycle of the plating metals and destruction of cyanide in plating wastewaters holds great potential for providing a cost-effective solution to this environmental problem.

The removal efficiency of electrolytic processes is decreased as the solution becomes more dilute. The metal concentration of plating rinse streams is very dilute compared with that of the plating tank solution. One method of increasing the removal efficiency in dilute solutions is to increase the surface area of the electrode upon which the metal is plated (catnode). The HSA Reactor is based upon a technology that is capable of removing toxic pollutants from metal finishing wastewaters by electro-deposition. The system utilizes a special carbon fiber cathode and a metallic anode, both nonconsumable. This system provides dramatically improved performance in terms of metal removal rates, compared with more conventional electrochemical techniques. The Reactor also can electro-oxidize and destroy cyanides to below detection limits at a cost much lower than that of the conventional alkali-chlorination process.

The development of the Reactor was begun by HSA Reactors/Systems of Toronto, Canada, a company formed to research, manufacture, and market electrochemical systems. The system is based upon research undertaken in 1974 by Drs. Das Gupta and Fleet in the Department of Chemistry at Imperial College, University of London, England. The system features the use of an electrochemical cell with graphite (carbon n fiber) electrodes designed to increase the mass transfer rates and thus increase the efficiency of the metal removal process. Early in 1975, this work was brought to the attention of Ian Kennedy, President of HSA Reactors, Limited, by Dr. A. Barringer, of Barringer Research, Toronto, an alumnus and visiting professor at Imperial College. During the latter part of May, with the help of numerous scientific and engineering consultants, an extensive test program was designed for the electrochemical system. This test program was conducted at Imperial College under the supervision of Mr. Kennedy in early June, 1975 with completely satisfactory results. An agreement to finance the ongoing research, development, and commercialization of the system was rapidly concluded and the company was incorporated on July 19, 1975.

The development of the HSA Reactor System has been followed by both the Environment Canada and the U.S. Environmental Protection Agency because of its capability to remove the heavy metal pollutants at their source, thereby avoiding the production of sludges. Earlier studies by the U.S. EPA and

Environment Canada indicated that the HSA Electrochemical Reactor concept has great promise for cyanide destruction and for the economical recovery of metals from dilute waste streams. The early HSA systems that were studied were plagued with development problems. Consequently, earlier attempts to perform technology evaluation were frustrated.

In 1984 HSA Reactors, Ltd. discontinued the manufacture and sale of equipment and licensed the technology. PCK Technology holds the exclusive world rights in the Metal Finishing and Electronic Interconnection industries to manufacture, use, and sell products employing patented high surface carbon fiber technology. PCK obtained the rights to the Electronic Interconnection industry on January 3, 1983 and the Metal Finishing rights on May 22, 1984 from the original company, HSA Reactors/Systems. Metal Removal Systems (MRS) is a business unit of PCK Technology Division of Kollmorgen Corporation. Since acquisition, Metal Recovery Systems (MRS) has made major changes in the design and packaging of the recovery systems which appear to be solving many of the operation and maintenance problems previously encountered. The high surface area carbon fiber electrodes upon which the technology is based remain essentially unchanged.

Improvements in operation of the original HSA Systems were made by the operating companies, many with assistance from Metal Removal Systems. With the improvement in operations, it was appropriate to again consider evaluation of in-plant performance. This project undertook the evaluation of HSA Systems for removal of cadmium, zinc, copper, and cyanide from plating shop waste-waters. After discussions with MRS representatives and a survey of HSA Reactor Systems in service, the decision was made that only the Cadmium Systems were sufficiently well-developed to merit evaluation.

SECTION 2

SUMMARY AND CONCLUSIONS

SUMMARY

Analytical results of the testing at six installations of the HSA reactor showed that the technology is capable of removing cadmium, zinc, and the cyanide associated with these solutions from electroplating dragout. The concentration of the metal and cyanide in the discharge from the following rinse was usually low enough to meet current effluent regulations. Those shops whose rinse overflows were unable to meet effluent regulations were experiencing equipment and/or operational problems at the time of testing. All sites tested had running rinses following the HSA tank.

The original project plan was to investigate the removal of cadmium, zinc, copper, and cyanide from wastewaters. After discussions with MRS and a survey of systems in operation, focus was shifted to those removing cadmium.

Table 1 shows the calculated concentration of the metal and cyanide in the effluent from a single running rinse following the HSA tank based upon the production rate observed and the analytical results of samples taken at the time of testing. It should be noted that the metal concentration of the running rinse overflow from the plating line being tested does not reflect the metal concentration in the plant effluent. Rinses from other plating operations such as cleaners, acid dips, etc., would dilute the plating rinse stream further. Therefore, even those shops which were experiencing abnormal conditions would likely be in compliance.

TABLE 1. PROJECTED METAL CONCENTRATION IN RINSE WATERS

	SOURCE MG/L	HSA TANK MG/L	RINSE MG/L
Plant #1 - Cadmium			
Sample Set 1	13400	154	1.06
Sample Set 2	15000	68	0.45
Sample Set 3	6980	21	0.14
Plant #2 - Zinc			
Sample Set 1	538	122	1.29
Sample Set 2	538	218	2.30
Sample Set 3	538	345	3.65
Plant #3 - Cadmium			
Sample Set 1	1980	2.50	B.D.*
Sample Set 2	2770	0.59	B.D.*
Sample Set 3	1640	0.46	B.D.*
Sample Set 4	1580	0.61	B.D.*
Plant #4 - Cadmium			
Sample Set 1	20400	140.00	0.22
Sample Set 2	20400	5.45	0.01
Sample Set 3	18900	29.20	0.05
Plant #5 - Cadmium			
Sample Set 1	4560	3200	11.67
Sample Set 2	7400	1240	4.52
Plant #6 - Cadmium			
Sample Set 1	29729	902	3.57
Sample Set 2	17954	3468	13.74

*B.D. = Below Detection

Plating shops utilizing the HSA recovery systems have been reluctant to reuse the recovered metal from the HSA cathodes in their plating baths because of the possibility of contamination with other metals. In addition, metal recycling firms have refused to accept the metals because of the unknown content of the metal. Table 2 lists the analyses of metal samples collected during the testing. The recovered cadmium proved to be 99.34-99.94 percent pure; zinc, 98.74-99.39 percent pure. These results indicate that the metals removed from the waste plating solutions are recovered in a form highly suitable for recycling into primary or secondary metals markets.

TABLE 2. PURITY OF RECOVERED METAL

SHOP NO.	PLATED METAL	COMPOSITION, % Cd	Cr	Cu	Fe	Ni	Zn
2	Zinc	.08	.32	.02	.75	.08	98.74
	Zinc	.04	.11	.02	.41	.04	99.39
3	Cadmium	99.94	.00	.01	.02	.02	.01
4*	Cadmium	25.08	1.59	43.86	13.48	14.53	1.10
5	Cadmium	99.63	.01	.07	.05	.08	.15
6	Cadmium	99.34	.00	.14	.34	.10	.07

*The HSA system had been used to dispose of a solution of nickel/copper stripping solution.

An attempt was made to determine the quantity of metal recovered during each cycle of the HSA reactor. At some shops, the metal from the spent cathodes is redissolved by reversing the current in a stripping solution. Other shops transfer the metal to stainless steel cathodes by electrolytic means. The stainless plates are then mechanically stripped of the metal. Depending upon the procedure at the particular shop, the weight of recovered metal is determined by either analysis of the stripping solution before and after stripping or weighing the cathodes before and after stripping.

Table 3 shows the weight of metal recovered from each cycle of the HSA system at the various test sites. The weight of recovered metal shows a variation of 159-44723 grams/cycle for cadmium; 150-559 grams/cycle for zinc. This wide range is attributable to the fact that the HSA cycle is determined on a time basis rather than upon the capacity of the cathodes. Wide variations in dragout rate caused by the type of parts plated and production fluctuations are experienced in the job shop. Such variations reduce the removal efficiency of the HSA system.

TABLE 3. METAL RECOVERED

SHOP NO.	METAL	METAL WT, G
1	Cadmium	159
1	Cadmium	273
1	Cadmium	1272
2	Zinc	229
2	Zinc	150
2	Zinc	559
3*	Cadmium	227
3*	Cadmium	227
3*	Cadmium	227
3*	Cadmium	227
4	Cadmium	5299
4	Cadmium	926
5	Cadmium	44723
5	Cadmium	8945
6	Cadmium	1923
6	Cadmium	3830

*Recovered metal at this snop was determined by weighing the cathode before and after stripping.

Operating and Maintenance Experience

Of the shops visited, all personnel felt that the HSA systems as delivered were not yet ready for industrial use. Specifically, extensive changes in piping and/or equipment were necessary before acceptable operation was attained. Some operators feel that there are still operating problems that need to be solved. The most obvious shortcoming of the equipment is the lack of instrumentation which would clearly indicate to the operator the status of the cathodes. Regeneration cycles have been determined on a trial-and-error basis. These cycles have generally been based on a fixed time rather than cathode capacity. These views probably stem from the fact that the HSA Systems were essentially prototypes, between lab research and production type units.

CONCLUSIONS

The HSA reactor is an effective means of removing cadmium, zinc, and cyanides from the dragout of electroplating operations. The following conclusions were reached as a result of observations and/or analytical results of samples from the test sites.

1. Any process change that will reduce the chemical load on the HSA system will improve its performance. The average concentration of the HSA tank and, therefore, the concentration in the solution dragged from it, can be lowered by utilizing a dragout tank (or a dragin/dragout tank) between the plating tank and the HSA tank.

2. Performance of the system was outstanding at Site #3. This is attributed to the fact that this site is a captive shop which has little variation in the parts plated. The chemical load on the HSA system is therefore relatively constant. Conversely, job shops experience widely varying load rates from the wide variety of parts plated. Performance of the HSA reactors at these shops reflected this variation and is thought to be related to operator interaction with the HSA System under variable conditions.

3. Additional research and development of the technology is warranted with the objective of producing systems with instrumentation to indicate when regeneration is required. In addition, the development of systems for removal of metals in addition to cadmium and zinc is desirable.

SECTION 3

BACKGROUND

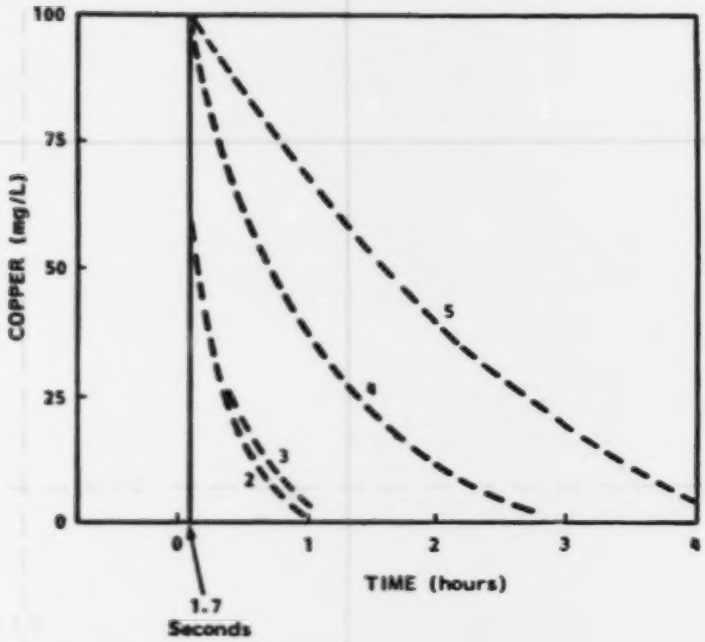
Electrochemical technology has been applied for many years to metal finishing. Developments have been limited, however, primarily because of poor mass transfer characteristics, that is, because of inefficiency in transporting the electro-active species from the bulk of the solution to the working electrode surface.

Classic plate-and-frame cells of the type used in copper electrowinning have poor mass transfer characteristics, and metal recovery rates are improved, for example, by vigorous stirring or air spraying of the solution. Attempts to improve mass transfer have resulted in the design of a number of three dimensional reactor designs where the reactor cell compartment is packed with metallic or conducting particles that are in turn fed by an electrical feeder plate or similar connection. Despite extensive research and development, this type of fluidized bed and the related packed bed suffer from an inherent design limitation in that when the process solution is forced through the particulate electrode, electrical contact is lost between adjacent electrode particles. This behavior results in nonuniformity of electrode potential throughout the bed and permits severe losses in current efficiency.

In the early seventies, investigators in England had been examining a number of different carbon-based electrode materials with the objective of developing flow-through sensors for on-line monitoring of heavy metals and organics. Studies of a number of vitreous-carbon-based samples led to the examination of an interesting carbon fiber material--one developed some years earlier, principally for use in structural composites in engineering applications.

The English investigators constructed a small electrochemical flow cell and conducted some standard voltammetric measurements. The electrochemical properties of the carbon fiber were interesting in that the material exhibited a high hydrogen and oxygen overvoltage, had a dense glass-like surface with minimal surface adsorption, and was ideally suited to the voltammetric detection of trace heavy metals. One serious limitation was immediately apparent, however; because of its enormous surface area, electrodes constructed of the material showed a very large background current caused solely by the capacitative charging of the electrode double layer. Although this limitation effectively eliminated any possibility of using the material as a microdetector, it was apparent to the investigators that the foregoing unique characteristics could be applied to the design of cells for the quantitative removal of metals from a dilute metal-bearing stream.

This observation was further studied and attempts to correlate the performance of the new carbon fiber reactor with alternative competitive designs provided startling results. The removal rates for various categories of electrochemical removal systems were obtained from the literature. The removal rate is defined, for the purpose of this comparison, as the time required for the particular reactor system to reduce the concentration of copper in an acidic copper electrolyte from 100 mg/L to below 1 mg/L. The removal rates as illustrated in Figure 1 demonstrate that, even in the case of the fluidized bed cell (the most advanced reactor design available in 1975), removal of copper to below the 1 mg/L level still required electrolysis time of approximately 1 hour. In the case of the HSA Reactor system, this process required 1.7 seconds.



1 -- HSA Carbon Fiber Reactor
2 -- Restrained bed cell, lead bead packing
(20-mm bed depth, 2.6-mm bead size)
3 -- Cell packed with 2-mm glass beads
4 -- Capillary gap cell packed with Netion
5 -- Parallel plate cell

SOURCE: A. Kuhn, "Novel Electrode Systems for Dilute Metal Bearing Liquors," Chemistry and Industry, July 1978.

Figure 1. Comparison of Performance of Different Electrochemical Reactor Designs with the HSA Reactor Performance for Copper Removal at the 100 mg/L Copper Level

This improvement was so dramatic that a detailed experimental test program was undertaken to confirm the observation with a number of other electrochemical systems. All the test results from a range of electrode processes confirmed the initial observations. The next step was to quantify the performance of the new concept in terms of a parameter known as space time yield. This standard chemical engineering parameter defines the performance of a system in terms of the quantity of a reactant converted to a product for a given reactor volume in a finite time. The data for reactor performance, as shown in Table 4, shows the improvement of the HSA Reactor system over the conventional designs. The data in the right-hand column have been normalized against a capillary gap cell, which can be considered a standard reactor design of fairly wide industrial application.

Table 4. Comparison of Reactor Performance

Type of Reactor	Specific Electrode Area (cm^2)	Space-Time Yield (mg/L/s)	Limiting Current (mA/cm^3)	Normalized Performance (mA/cm^3)
Filter press	0.3-1.7	0.12-0.68	0.6-8.8	1.0
Capillary gap	1.0-5.0	0.40-2.00	0.6-8.8	3.0
Rotating or wiped cathode	0.1	0.4	2.0-4.5	1.0
Packed bed	10-50	4-20	4-25	3.0
Fluidized bed	20-100	8-40	10-60	60
HSA Carbon Fiber Reactor	34,000	13,600	6,800	34,000
Catalytic reactors	--	0.007-250	--	--

From these early experiments it was evident that the carbon fiber reactor concept provided dramatically improved performance, in terms of metal removal rates, compared with all competitive electrochemical and alternative technologies. The potential for application to a number of metal recovery technologies -- including pollution control, hydrometallurgy, and resource recovery -- were immediately obvious. There was also the prospect that many existing electrotechnologies that had been dormant for many years, such as electro-organic synthesis, might be revitalized by this novel electrochemical reactor design concept.

As shown in Figure 2, the HSA unit is connected in a closed-loop fashion to a process tank that follows a plating bath. The solution from the process rinse is pumped through a filter to remove particulate matter that would reduce the treatment efficiency of the Reactor, and through the Reactor

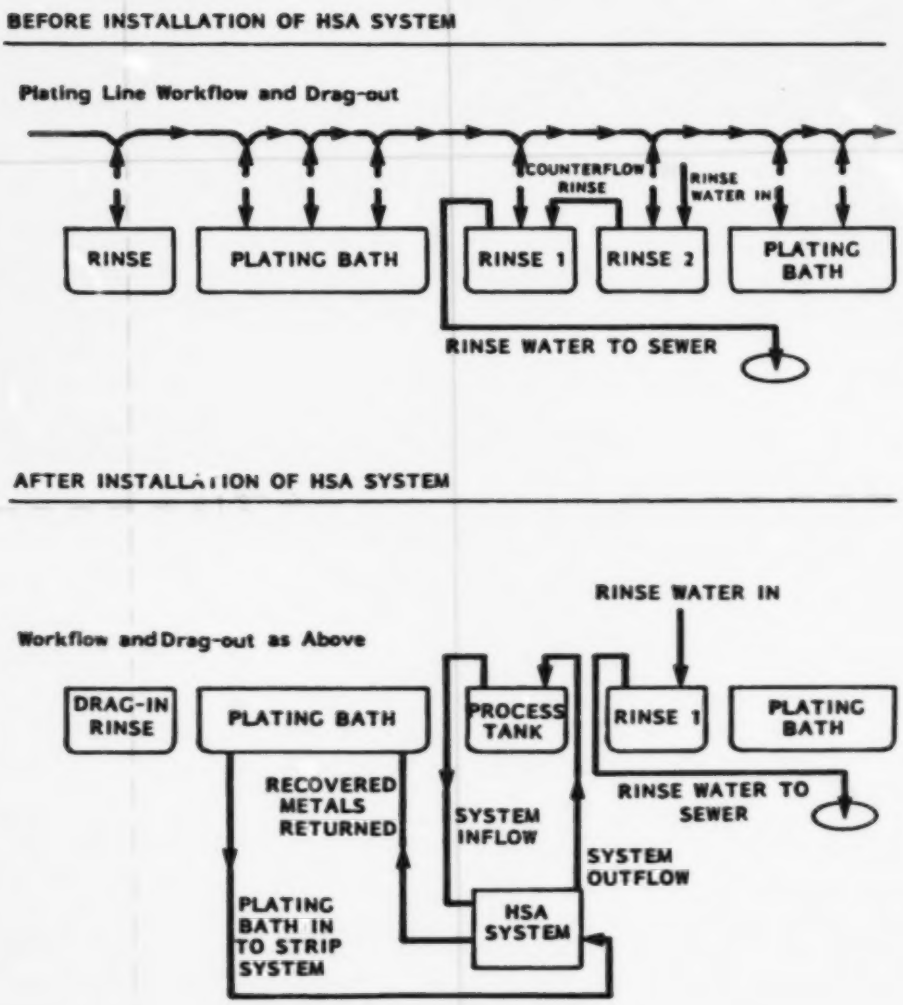


Figure 2. Layout of Typical Plating Line Operation

modules, which house the high-surface-area carbon fiber cathode. A Reactor can be equipped with one to four modules to meet the capacity requirements of various applications. The power for the treatment process is supplied by a common rectifier. The treated water is returned to the process tank. The overflow rinse following the process rinse can be sewered after pH adjustment.

When the loading of the cathodes is complete, flow from the drag-out rinse is cut off. Metal is then stripped from the cathode either chemically or electrochemically, depending on the type of metal. A stripping solution is circulated through the carbon fiber, redissolving the previously deposited metal. The stripping solution can be plating bath recirculated directly from the bath or from a separate strip tank, which can be located below the modules. The stripped metals in the stripping solution can be returned to the plating bath to replenish the metal removed in the plating process or plated onto a starter sheet from which it is subsequently removed and sold as scrap metal. A typical installation is illustrated in Figure 3.

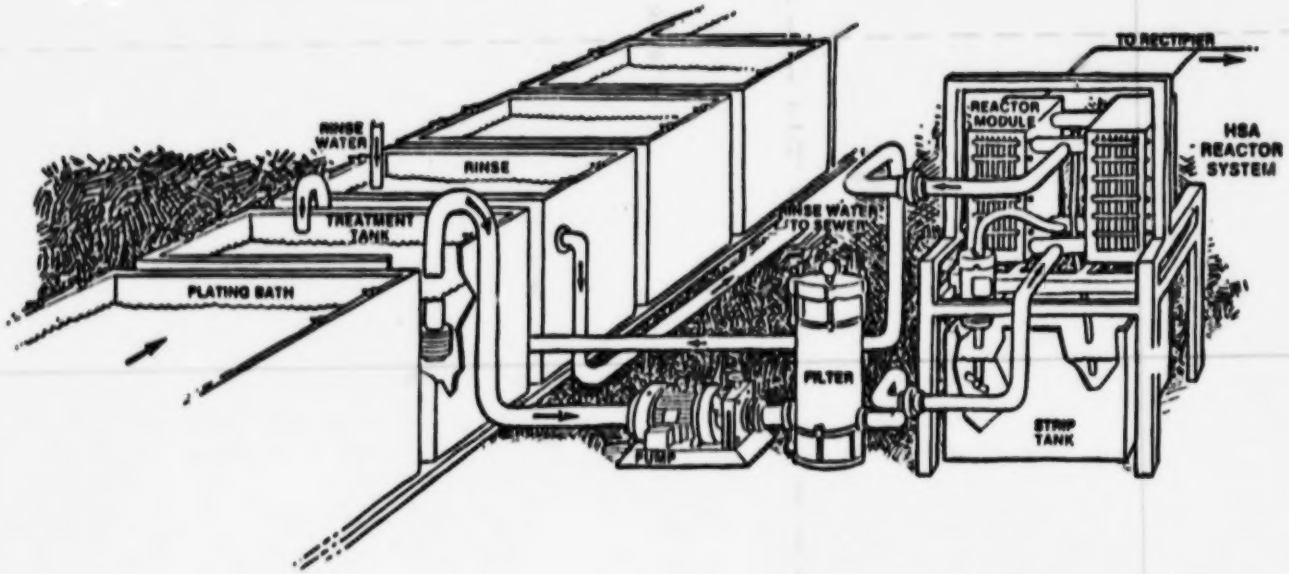


Figure 3. Process Flow Diagram: HSA Reactor System

SECTION 4

SAMPLING PROCEDURES

Several piping and tank arrangements are utilized in the installation of the HSA recovery systems. All are variations of the scheme shown in Figure 4. Tank 1 is usually a still rinse (dragout) tank following the plating tank. This tank is sometimes used as a dragin/dragout tank, i.e., the work passes through this tank before and after the plating operation. In the case of automatic lines, two tanks often serve the dragin/dragout function. A pump circulates the solution through the tanks to maintain a uniform concentration. The concentration of the various constituents of the DI/DO tank is constant and approximately one-half that of the plating tank.

Tank 2 is the tank from which solution is pumped to the recovery unit. Solution is returned to this tank after passing through the recovery system.

Tank 3 represents the solution containing the recovered metal after regeneration of the cathodes. Recovered metal is removed from the cathodes by several methods:

1. Redissolving by reversing current
2. Electrolytically transferring the metal to stainless steel plates; then mechanically removing the deposit.
3. Placing the cathodes loaded with collected metal in the plating tank and redissolving the metal.

In cases where the metal is redissolved by reverse current, this tank is usually located below the electrolytic recovery tank.

Sampling Approach

Sampling and analysis will be designed to determine the removal efficiency of the HSA system, i.e., what percentage of the metal in the drag-out is being removed. Samples will be collected during a cycle of the HSA system (from regeneration to regeneration). Composite samples of process tanks will be collected throughout the production period.

Specific sampling procedures for the three common operating procedures listed above are planned as follows:

Regen. Method	Tank 1	Tank 2	Tank 3
1. Reverse Current	Composite	Composite	Grab
2. Metal Transfer	Composite	Composite	Weigh Metal or dissolve in acid and analyze.
3. Return cathodes to plating tank	Composite	Composite	Weigh Cathodes or dissolve and analyze

Samples from Tanks 1 and 2 will be composites to be analyzed for the plated metal and cyanide. (e.g., cadmium plating lines will be sampled for cadmium and cyanide analyses; brass lines for copper, zinc, and cyanide analyses.)

Samples from Tank 3 will consist of one grab sample at the end of each regeneration cycle to determine the mass of the specific metal removed in the system over the operating period. This analysis is for the appropriate metal only. In the cases in which the recovered metal is not redissolved by reverse current, weighing of the stripped metal or the loaded cathodes will provide this information.

It should be understood that production considerations or installation variations at a particular installation may require deviations from this procedure in the interest of the most accurate results.

Additional Data

In addition to the samples collected, production data such as the type of parts plated, racks/hour, dragout rates, etc. will be recorded as required.

Volumes of solutions, such as the regenerant, will be determined by calculation using measurements of the geometric shape of the tanks.

Referring to Figure 4, the quality of the plated metal in the dragout from Tank 1 (M1) is equal to the sum of that recovered by the HSA Reactor (M3) plus that in the dragout from Tank 2 (M2). M3 can be determined from the volume and analysis of the regenerant or the measured weight of the metal recovered. M1 can be determined from the analysis of Tank 1 and the dragout rate. (The dragout rate is determined from the type of plating, rack or barrel, and the geometry of the parts being plated.) The percentage of metal recovered is then:

$$\% \text{ Metal Recovered} = \frac{M3}{M1} \times 100$$

Composition of recovered metal

Metals recovered by the HSA Reactor are presenting a disposal problem for plant operators. Many are reluctant to recycle the recovered metal to the plating bath in fear of contaminating it. Reclaiming companies are reluctant to accept recovered metals because the composition is unknown. In order to provide this information, samples of metal recovered by the HSA Reactor will be collected and analyzed for composition.

Sampling duration will be at least 5 days and a minimum of three cycles of the recovery system.

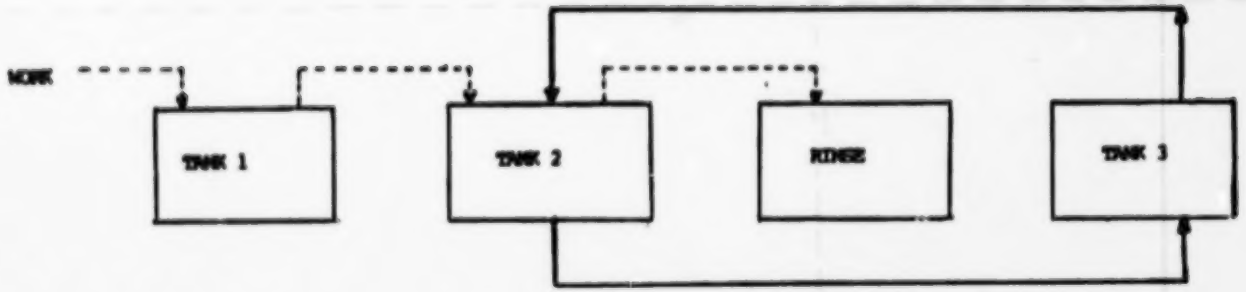


Figure 4. HSA Reactor Typical Arrangement

SECTION 5

SITE EVALUATION DESCRIPTIONS

SITE 1

Description

At Site 1, a medium-sized job shop serving the metropolitan Detroit area, cadmium, zinc and tin are plated. Plating lines include manual rack and barrel lines as well as a large automatic rack cadmium line. The facility provides quick turnaround of hard-to-plate materials for the automotive, trucking, aerospace industry and the military as well as an assortment of other local industries. The HSA system was installed to treat cadmium rinse waters and to reduce cadmium in the sludge generated by the industrial waste treatment system and to better enable Site 1 to comply with the City of Detroit effluent regulations.

Plating Operation

This shop operates a 30 station Udylite automatic rack line plating cadmium. The line has seven stages prior to plating. These stations include alkaline cleaner, and acid dip. There are 14 cadmium plating stations. Following plating, there are nine stations, including a still rinse following the plating tank, the HSA rinse following the still rinse, followed by overflow rinses and two stations for movable chromate tanks. Because the plating tank begins on one side of the unit and ends on the other side, therefore requiring a drag-in tank to be located directly across from the present drag-out tank, implementation of a drag-in/drag-out configuration would be very difficult. Line speed ranged from 65 seconds per rack to 88 seconds per rack with an average speed of 78.5 seconds per rack. Plating tank residence time averages 18 minutes 20 seconds.

HSA System

Site 1 operates an eight element metal removal system (MRS-401-8,), and an eight element cyanide destruct system (MCN-401-8). The cathode elements in the metal removal system are stripped by reverse current and oxygen in a plating bath solution (MCS-401-8). The solution has not been replaced or removed since the system has been in use.

During the initial visit, the owner stated that the plating line, when at full production, normally operated approximately 14 hours per day. The HSA system normally operated 20 hours per day. Regeneration was done once per day between midnight and 4 am.

The rectifier in the metal removal circuit was operated between 3 and 4.5 volts and between 700 and 920 amps. The rectifier supplying power for the cyanide destruction circuit was operated between 5 and 8.5 volts and between 450 and 800 amps.

HSA Tests

A wide range of geometrically shaped material is plated at Site 1. During the sampling period, the line changed material between 5 and 11 times per day. Maximum number of pieces racked were 144 per rack and minimum number was 1 part per rack. The material observed that causes the most dragout was what appeared to be a four belt pulley approximately 5-6" dia. Material producing minimal dragout included various shapes of bolts and king pins.

The original sampling strategy was designed to characterize the cadmium and cyanide removal capabilities of the HSA. The specific design is as follows:

1. Composite sample of the still rinse after the plating tank.

2. Composite sample of the rinse connected to the HSA unit (after the still rinse).

3. The composite samples would be one cycle in duration. A cycle is defined as the time of HSA operation between regenerations.

4. An initial grab sample of the regenerate solution before the first cathode strip followed by a grab sample of the regenerate after each catode regeneration.

5. A total of five cycles would be sampled over a five day production week.

The sampling plan was successfully executed with the exception of the number of cycles sampled. Due to lower actual production than anticipated, the cathodes were regenerated three times over the week.

Actual operating schedule during sampling was as follows:

Day	HSA	Plating Line	Regeneration
1	10 hrs 18 min	10 hrs 00 min	
First regeneration:			12 hrs 30 min
2	12 hrs 15 min	07 hrs 06 min	
3	12 hrs 47 min	07 hrs 24 min	
4	07 hrs 07 min	07 hrs 02 min	
Second regeneration:			16 hrs 45 min
5	04 hrs 43 min	04 hrs 29 min	
Third regeneration:			09 hrs 15 min

General Operation and Maintenance of the HSA System

- Regeneration of cathodes - Routinely regenerated 3 to 5 times per week.

- Cathode rinse -- Site 1 follows the recommended procedure of rinsing cathodes in a fresh water rinse tank before installing the cathodes in the regenerate system. An experienced worker expends not less than 1/3 to 1/2 hour per cycle removing the bus bar, rinsing the eight cathodes, inserting each into the regenerate system, installing the regenerate system bus bar and starting the system. Two bolts on the bus bar must be individually tightened and tensioned for each of the eight cathodes. The following procedure is repeated when the cathodes are returned to the metal removal system.

- Oxygen cylinder change - Oxygen is rapidly used during regeneration. Cylinders must be manually moved from the loading area to and from the HSA site which is adjacent to the plating line. Oxygen storage also requires safety chains and a special cylinder hand truck.

- Operations schedule - Site 1 regenerated the HSA cathodes on a variable schedule as determined by the owner. Orders were then given to the workers to perform needed tasks. The owner relied on past experience regarding elapsed time since the last cathode change and dragout loading on the plating line. There were no measurements or analyses to base a decision on.

- Repair - The HSA system contains various valves, visiting this site previously, an oxygen flow meter failed when the system was being demonstrated.

- Manpower - The owner stated that the HSA system requires 2 man hours per day to operate during full production.

- Cost - The owner stated that the total investment is about 1.5 to 2.0 times the cost of the system alone. The additional cost was for required items not provided by HSA. These included pumps, electrical service, plumbing, and other miscellaneous equipment.

TABLE 5. PERFORMANCE AT SITE 1

Run	CADMIUM, MG/L		CYANIDE MG/L		Cd, MG/L
	Still Rinse	HSA Tank	Still Rinse	HSA Tank	Regen.**
1	13,400	154	*	111	20,700
2	15,300	67.6	2,990	49.5	21,900
3	6,980	21.1	4,690	30.0	27,500

* sample lost during distillation, text cancelled.
** concentration in the regeneration tank after a series of cathode regenerations.

TABLE 6. DATA SHEET FOR SITE 1

PLANT DATA

PLANT OPERATION:	24 HRS/DAY
PLATING LINE OPERATION	14 HRS/DAY

HSA DATA

HSA OPERATION	20 HRS/DAY
METAL RECOVERED	Cadmium
MODEL NO.	MRS401-8, MCN401-8, MCS401-8
SIZE:	8 Element
DRAGOUT SOURCE:	Still Rinse
PLATING LINE SERVICED:	1 automatic rack line
REGENERATION FREQUENCY	every other day
STRIPPING METHOD:	reverse current with oxygen into solution
RECTIFIER SETTINGS:	3-4.5 volts 700-920 amps

SITE 2

Description

The second site, Site 2, is a medium-sized job shop serving Erie and Northern Pennsylvania. Cadmium, zinc and nickel plating, and various surface coatings such as anodizing, alodining, chromating and miscellaneous bright dips are performed. Plating lines include manual rack and barrel lines. The facility plates a wide variety of materials ranging from electronics cabinets to materials for the transportation industry and fastener industry as well as material from an assortment of non-related local industries. HSA systems were installed to reduce zinc and cyanide in the final industrial waste discharge.

Plating Operation

Two metal HSA serves serving two manual rack lines and a manual barrel line. The cathode elements in the metal removal system are regenerated by reverse current in a plating bath solution on to stainless steel sheets. The metal is mechanically removed and/or acid stripped from the stainless steel plates and not reused. Each line discharges rinse water to a central sump which then recirculates through both HSA systems working in tandem. (Figure 5)

The tanks for rack work are the long narrow type. Manually operated hoists transport long bars which hold up to 50 racks of material. A single cleaning line handles all standard alkaline cleaning, acid dips and associated rinses before plating for both rack lines. Bars are moved from the center cleaning line on dollies to the outside lines for plating. A certain amount of drip occurs during this transfer operation. The tank arrangement on the two rack lines are not in progressive order. A single tank is used as a rinse

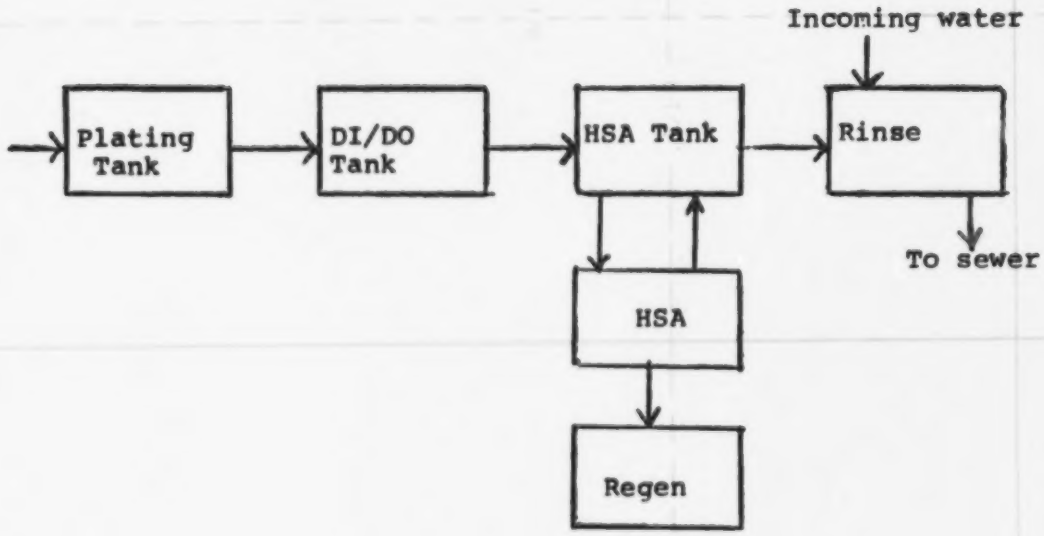


Figure 5. Process Flow Diagram for Site 2

both before and after plating and serces as a drag-in/drag-out tank. The drag-in/drag-out technique is a matter of procedure rather than tank configuration. An overflow rinse follows on each of the plating lines. Line speed ranged from 4 minutes per rack to 15 minutes per rack.

The barrel line is conventional four (4) place plating followed by a barrel dump station, HSA rinse station, hot rinse, extractor, and associated chromate dips. This operation is also split in terms of pre-plate procedures. The material cleaning setup serves more than one barrel plating operation. The barrel line recirculates the drag-out rinse following the barrel dump station

HSA System

During the initial visit, plant personnel stated that, at full production one rack line operated usually 2 shifts (approximately 12-16 hours per day), one rack line operated usually 1 shift (approximately 4-8 hours per day), the barrel line operated usually 1 shift (approximately 6-8 hours per day), the HSA system operated when two plating lines were running, and regeneration was done usually once per week or as needed.

Their metal removal rectifier was operated between 2.9 and 4.5 volts and between 700 and 920 amps. The rectifier supplying power for the cyanide destruct was operated at 5.0 and 8.5 volts and between 450 and 800 amps.

HSA Tests

A wide range of geometrically shaped material is processed at this site. During the sampling period, the line changed material between 3 and 5 times per day. Maximum number of pieces processed at one time were 1242 pieces per bar and minimum number was 2 pieces per bar. The product observed that causes the most dragout was a box shaped computer cabinet. Products producing minimal dragout included various shapes of bolts and metal rod.

The original sampling strategy was designed to characterize the zinc and cyanide removal capabilities of the HSA. The specific design is as follows:

1. Composite sample of the still rinse after the plating tank.

2. Composite sample of the rinse connected to the HSA unit (after the still).

3. The composite samples would be one cycle in duration. A cycle is defined as the time of HSA operation between regenerations.

4. An initial grab sample of the regenerate solution before the first cathode strip followed by a grab sample of the regenerate after each cathode regeneration.

5. A total of five cycles would be sampled over a five day production week.

The sampling plan was successfully executed with the exception of the number of cycles sampled. Due to lower actual production than anticipated, the cathodes were regenerated three times over the week.

Actual operating schedule during sampling were as follows:

Day	HSA Operating Time
1	7 hrs 15 min
2	12 hrs 10 min
3	13 hrs 10 min
4	7 hrs 35 min
5	6 hrs 25 min

The barrel line operated one shift (8 hrs) per day. The primary rack line operated two shifts per day. The secondary rack line operated second shift three days and first shift three days.

General Operation and Maintenance of the HSA System

- The HSA system has caused anxiety at this location by shutting down for no apparent reason while sampling was being done.
- Plant personnel see a distinct need for real time monitoring to determine operation/efficiency of the unit.
- Site 2 believes that the final installed price was far more than anticipated as compared to the original purchase price.
- O & M manpower is estimated at 10 manhours per week.

TABLE 7 PERFORMANCE AT SITE 2

	ZINC, MG/L		CYANIDE, MG/L		Zn, MG/L
Run	Di/Do* rinse	HSA Tank	Di/Do rinse	HSA Tank	Regen.
				initial	0.70
1	590 (barrel) 336 (rack 1)	122		950	3030
2	687 (rack 2) (rack 1)	218	10,000 10,000	949	5010
3		345		951	12,400

* Di/Do rinse is the concentration of zinc in the rinse from the drag-in & drag-out rinse operations.

TABLE 8. DATA SHEET FOR SITE 2

PLANT DATA

PLANT OPERATION:	16-24 HRS/DAY
PLATING LINE OPERATION:	8-16 HRS/DAY

HSA DATA

HSA OPERATION:	8 hours 55 minutes hrs/day (geometric mean)
METAL RECOVERED:	Zinc
MODEL NO:	MRS401-4, MCN401-12, MER401-4
SIZE:	4 element cyanide destruct 1-4 element and 1-8 element metal removal
DRAGOUT SOURCE:	drag/in-drag/out rinse
PLATING LINES SERVICES:	2 manual rack lines and 1 manual barrel line
REGENERATION FREQUENCY:	2 - 3 times per week
STRIPPING METHOD:	reverse current on to stainless steel reclaim sheets
RECTIFIER SETTINGS:	Metal removal 2.9 - 4.5 volts 700 - 920 amps cyanide destruct 5.0 - 8.5 volts 450 - 800 amps

SITE 3

Description

Site 3 is a large captive shop serving a well know industry. Plating operations observed during the visit include cadmium, chrome, and silver. Plating lines include manual rack and automatic rack lines. The product plated during the visit was a steering arm pivot shaft. The HSA system was installed to reduce cadmium in the sludge generated by the industrial waste treatment system and to better enable Site 3 to comply with local regulations.

Plating Operation

Site 3 operates a hand rack line plating cadmium. The line has four stages prior to plating. These stations include alkaline cleaner, acid dip and a drag-in/ drag-out rinse tank. There are two plating tanks each with two stations for a total of four plating stations. Following plating, there is a drag-in/drag-out tank followed by an hot still rinse. Material is individually racked. The racks are then hung on a bar. Number of racks to a bar varies according to the size of the product plated. According to Site 3 time study guidelines, the line averages 4 racks each 45 minutes of operation.

HSA System

A four element HSA metal removal system (MRS-201) is installed at Site 3. The cathode elements in the metal removal system are stripped by reverse current in a plating bath solution (MCS-201) on to stainless steel sheets. The metal is mechanically removed and/or acid stripped from the stainless steel plates and not reused. During the initial visit, the owner stated that the plating line, when at full production, normally operated 24 hours per day. The HSA system normally operated 24 hours per day. Regeneration was done once per week or as needed. Site 3 production operates on a three shift schedule. The first shift begins at 0700 hrs, the second at 1500 hrs and the third at 2300 hrs. Site 3 operated their metal removal rectifier between 2.9 and 4.5 volts and between 700 and 920 amps.

HSA Tests

Site 3 plates one geometrically shaped product although the size may change periodically. During the weeks observations, the part changed only once, which was at the beginning of the third shift on the first day. The original sampling strategy was designed to characterize the cadmium removal capabilities of the HSA. The specific design is as follows:

1. Composite sample of the drag-in/drag-out rinse after the plating tank

2. Composite sample of the rinse connected to the HSA unit (after the drag-in/drag-out rinse).

3. The composite samples would be one cycle in duration. A cycle is defined as the time of HSA operation between regenerations.

4a. An initial sample of the regenerant before the first cathode strip followed by a sample of the regenerant after each cathode regeneration.

or 4b. An initial weight of the cathodes before the first cathode strip followed by a weight of the cathodes after each cathode regeneration.

or 4c. An initial weight of the cathodes before the first cathode strip followed by a weight of the cathodes over a period of time.

5. A total of five (5) cycles would be sampled over a week's (5 days) production.

The sampling plan was successfully executed using option 4c with the exception of the number of cycles sampled. Due to lower actual production than anticipated, there were four cycles measured over the week. A twenty-four (24) hour period of time was chosen since Site 3 maintenance personnel shut down the HSA at 1135 hrs on Day 1 to change cathodes and regenerate the used cathodes.

Line production during sampling was as follows:

Day	shift	number of pieces per rack	total number of pieces
1	1	18	432
1	2	10	253
1	3	10	808
2	1	10	300
2	2	10	430
2	3	--	0
3	1	10	360
3	2	10	380
3	3	--	0
4	1	10	399
4	2	10	400
4	3	--	0
5	*1	10	260

NOTE: Shift one, day five recorded until noon when HSA was shut down for regeneration.

Cathode Weights

Since the HSA was shut down for cathode change near noon on day 1, the cathodes were weighed before installation. The HSA unit was shut down each day thereafter at exactly the same time and the cathodes were weighed on a digital scale provided by Site 3. The weights recorded on days 2 through 5 were consistent with expectations whereas the first weighing was not. This is attributed to the difference in the amount of water retained in the cathode at the time of weighing on the first day versus the remaining days. The following table shows the combined weights obtained:

Day	Combined weight (lbs)
1	97.5
2	96.5
3	97.0
4	97.5
5	98.0

General Operation and Maintenance of the HSA system

- Regeneration of cathodes -- Although production related, no clearly defined schedule.

- Cathode rinse and transfer time -- HSA suggests that each cathode be thoroughly rinsed before transferring from the MER system to the MCS system. In view of the fact that there are four elements, the rinsing is time consuming. Included in this time are the following steps:

1. Loosen two contact bolts extending from the bus bar to each of the four elements.

2. Remove the bus bar from atop the unit.

3. Rinse each individual element.

4. Transfer each element to the MCS (each element weighs approx 25 lbs)

5. Install the bus bar atop the MCS unit.

6. Tighten two contact bolts extending from the bus bar to each of the four elements.

- Operation schedule of HSA relative to plating line production Site 3 usually operated the HSA/MER approximately 24 hours per day five (5) days per week. Site 3 customized the HSA down time schedule to accommodate the sampling.

- Repair of the HSA included various maintenance items such replacing pump seals, electrical contacts, and flow instrumenta,tion. There were also modifications made to the original plumbing system to eliminate certain hydraulic problems.

- Manpower estimated by Site 3 to operate the HSA was 1 to 1-1/2 nours per shift of non-technical labor during full production.

- No operations and maintenance manual. Site 3 believes that most of the operations knowledge came from experience rather than instruction.

- Hardware failure since installation included pump seals, valves, and assorted small parts. Site 3 believes that the hardware technology can be greatly improved over their present system even though they have made numerous minor hardware improvements on their own.

- Cathode life is of great concern. Site 3 believes that due to the extremely high cost of cathodes, the life of the elements are relatively short.

- Breakdown troubleshooting appears to be a problem. Site 3 believes that more instrumentation would enable the owners to do a better job of problem diagnosis since down time is critical.

- Major complaint in terms of cost is that Site 3 estimates that the final cost of the system has been approximately 150% of the original purchase price.

TABLE 9 PERFORMANCE AT SITE 3

	CADMIUM, MG/L		CYANIDE, MG/L		Cd,lbs
Run	DiDo* Rinse	HSA Tank	DiDo Rinse	HSA Tank	Regen.
0	na	na	na	na	97.5
1	1098	2.52	10,250	0.4	96.5
2	2770	0.59	10,750	0.6	97.0
3	1640	0.46	12,250	0.1	97.5
4	1580	0.61	11,250	0.2	98.0

TABLE 10 DATA SHEET FOR SITE 3

PLANT DATA

PLANT OPERATION:	24 HRS/DAY
PLATING LINE OPERATION	24 HRS/DAY

HSA DATA

HSA OPERATION	23 hrs/day
METAL RECOVERED:	Cadmium
MODEL NO:	MRS401-4
SIZE:	4 element
DRAGOUT SOURCE:	drag/in-drag/out rinse
PLATING LINES SERVICES:	1-manual rack line
REGENERATION FREQUENCY:	once per week
STRIPPING METHOD:	reverse current
RECTIFIER SETTINGS:	2.9 - 4.5 volts
	700 - 920 amps.

SITE 4

Description

Site 4 Corporation is a medium size job shop operating in suburban Chicago. Plating operations observed during the visit include cadmium, zinc, nickel, and tin along with various surface coatings such as chromates. Operations include manual rack and manual barrel plating lines. The facility provides quick turnaround of small hard to plate materials for the automotive industry, electrical industry and the military as well as an assortment of non-related local. The HSA system was installed to reduce cadmium in the sludge generated by the industrial waste treatment system and to better enable Site 4 to comply with the Chicago Metropolitan Sanitary District effluent regulations.

Plating Operation

Two plating lines are connected to the HSA system at Site 4. The barrel line contains multiple plating tanks which include cadmium and zinc. The specialty rack line plates a number of metals including nickel, cadmium and tin. The lines are both manually operated. The rack line is operated without a hoist. Platers on both lines pass material through the HSA tank only when plating cadmium. There is no rinse tank between the plating tank and the HSA rinse tank on either line. Both lines contain pumps which feed to and receive from a central tank located under the HSA system. (Figure 6)

HSA System

Site 4 operates an eight element metal removal system (MRS-401-8), and a twelve element cyanide destruct system (MCN-401-12). The cathode elements in the metal removal system are stripped by reverse current whereby the cadmium is replated on to stainless steel reclaim sheets in a plating bath solution (MCS-401-8). During the initial visit, plant personnel stated that the plating lines, when at full production, normally operated approximately 18-20 hours per day. The HSA system normally operated 18-24 hours per day. Regeneration was done once every 3 - 4 days between midnight and 6 am.

Site 4 operated their metal removal rectifier between 12 and 13 volts and between 180 and 275 amps. The rectifier supplying power for the cyanide destruct was operated between 1.2 and 1.5 volts and between 180 and 275 amps.

HSA Tests

Site 4 plates a wide range of geometrically shaped material on the specialty rack line. During the sampling period, the line changed material between 2 and 8 times per day. Maximum number of pieces plated per day were 10679 and the minimum number was 1400 pieces per day (when the line was operating). The material is either racked on conventional racks or tied to a rack using 14 gauge copper wire. Shapes include small rectangular sheets, small boxes, rings, strips, and many other odd shaped pieces that are not amenable to barrel plating. The barrel plating line plates many small fasteners and items not needing the quality usually provided by rack lines or items not able to be racked.

The original sampling strategy was designed to characterize the cadmium and cyanide removal capabilities of the HSA. The specific design is as follows:

1. Composite sample of the plating tank.

2. Composite sample of the rinse connected to the HSA unit (after the plating tank)

3. The Composite samples would be one cycle in duration. A cycle is defined as the time of HSA operation between regenerations.

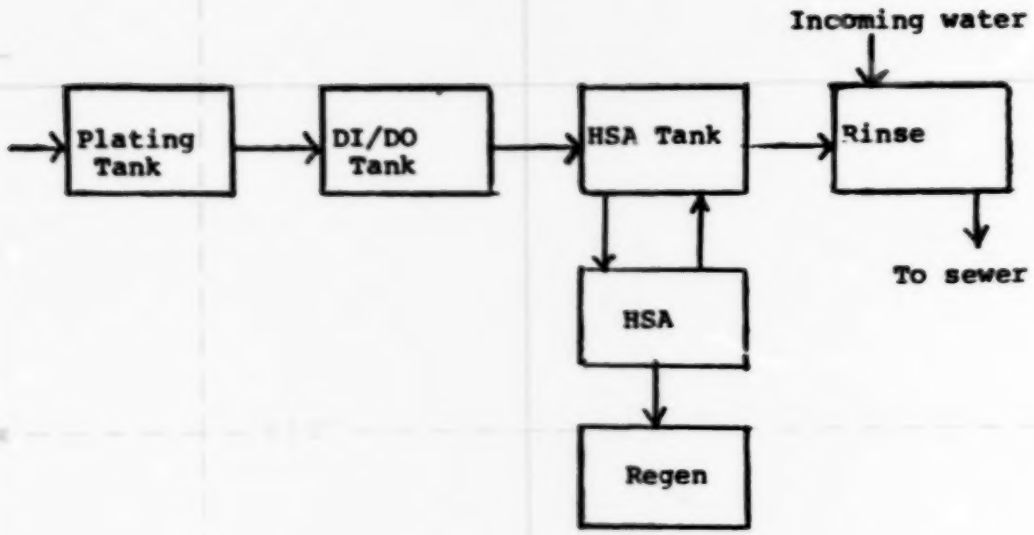


Figure 6. Process Flow Diagram for Site 4

4. An initial grab sample of the acid strip solution used to strip cadmium from the stainless steel regenerate sheets followed by a grab sample of the acid strip after each cathode regeneration.

5. A total of three (3) cycles would be sampled over a week's (5 days) production.

The sampling plan was successfully executed with the exception of the following:

1. A pump failed on the barrel line HSA tank. This situation was not remedied during the sampling session. Site 4 shut down the HSA tank and utilized it as a still rinse (dragout) tank.

2. A rectifier malfunctioned on the HSA system prior to sampling. The plant manager had contracted for the rectifier to be repaired during the weekend following the sampling visit. The rectifier provided a lower than normal output in both the metal recovery and the cathode regeneration cycles. This is also thougnt to be the fault of a problem that occurred on day five where cathodes containing only 6-1/2 hours of plating line usage failed to automatically complete regeneration in over 17 hours of regeneration time.

Actual operating schedule during sampling was as follows:

Day	HSA	Plating Line	Regeneration
1	17 hrs 15 min	9 hrs 30 min	
2	14 hrs 00 min	0	
3	17 hrs 15 min	9 hrs 30 min	
First regeneration:			6 hrs 30 min
4	10 hrs 20 min	9 hrs 30 min	
Second regeneration:			7 hrs 30 min
5	6 hrs 50 min	9 hrs 30 min	
Third regeneration:			*

* Regeneration mode checked after 18 hours. System apparently malfunctioned. Test aborted.

General Operation and Maintenance of the HSA System

- Site 4 is enthusiastic about the system although the manager stated that the final system, as it stood at the time of testing, cost over 150% of the original purchase price.

- Site 4 believes that the initial system was difficult to install.

- Site 4 stated that the reduction of sludge at the waste treatment plant was the primary reason for the purchase.

- Manpower costs are approximately 2 manhours per day (10hrs/wk).

TABLE 11. PERFORMANCE AT SITE 4

	CADMIUM, MG/L		CYANIDE, MG/L		Cd,MG/L	
Run	Plating Tank	HSA Tank	Plating Tank	HSA Tank	Regen.	
1	20,400	140	86,500	0.02	16.7	before
					110	after
2		5.45		0.02	2.0	before
					18.3	after
3	18,900	29.2	72,000	0.02	*	

* aborted due to regeneration malfunction

TABLE 12. DATA SHEET FOR SITE 4

PLANT DATA

PLANT OPERATION: 24 HRS/DAY
PLATING LINE OPERATION: 9-1/2 HRS/DAY

HSA DATA

HSA OPERATION: 10 - 17 HRS/DAY
METAL RECOVERED: Cadmium
MODEL NO: MRS401-8, MCN401-12, MER401-8
SIZE: 8 element
DRAGOUT SOURCE: Plating tank
PLATING LINES SERVICED: 1 - manual rack line, 1 - manual barrel line
REGENERATION FREQUENCY: every 3 - 4 days
STRIPPING METHOD: reverse current
RECTIFIER SETTINGS: metal removal
12 - 13 volts and
180 - 275 amps.
cyanide destruct
1.2 - 1.5 volts
180 - 275 amps.

SITE 5

Description

Site 5 is a medium size job shop operating in the Kansas City Metropolitan area. Plating operations observed during the visit include cadmium, copper, nickel, and chrome along with various surface coatings such as chromates. Operations include manual rack and manual barrel plating lines. The facility provides quick turnaround of small hard to plate materials for a wide assortment of industries and the military. The HSA system was installed to reduce cadmium and better enable Site 5 to comply with the local sanitary district effluent regulations.

Plating Operation

One plating line is connected to the HSA system at Site 5. The barrel line contains multiple plating tanks which include cadmium and zinc. The line is manually operated. Platers pass material through the HSA tank only when plating cadmium. There is a drag-in/drag-out rinse tank between the plating tank and the HSA rinse tank on line. (Figure 7)

HSA System

Site 5 operates a four element metal removal system (MRS-201), and a four element cyanide destruct system (MCN-201). The cathode elements in the metal removal system are stripped by reverse current whereby the cadmium is stripped back into solution for reclaim. Site 5 operated their metal removal rectifier at 3 volts and between 500 and 650 amps.

HSA Tests

During the initial visit, the owner stated that the plating line, when at full production, normally operated approximately 8 - 10 hours per day. The HSA system operates when the plating line does. Regeneration was done once per week.

Site 5 plates a wide range of geometrically shaped material on the barrel line. Material plated includes (primarily) fasteners, brackets, and military ordinance along with small lots of other odd shaped pieces that are not amenable to rack plating. During the sampling period, the line changed material between 1 and 5 times per day. Maximum number of barrels processed were 24 per day and minimum number was 12 barrels per day. The material observed that causes the mose dragout was military ordinance casings.

The original sampling strategy was designed to characterize the cadmium and cyanide removal capabilities of the HSA. The specific design is as follows:

1. Composite sample of the drag-on/drag-out rinse tank.

2. Composite sample of the rinse connected to the HSA unit (after the drag-in/drag-out tank)

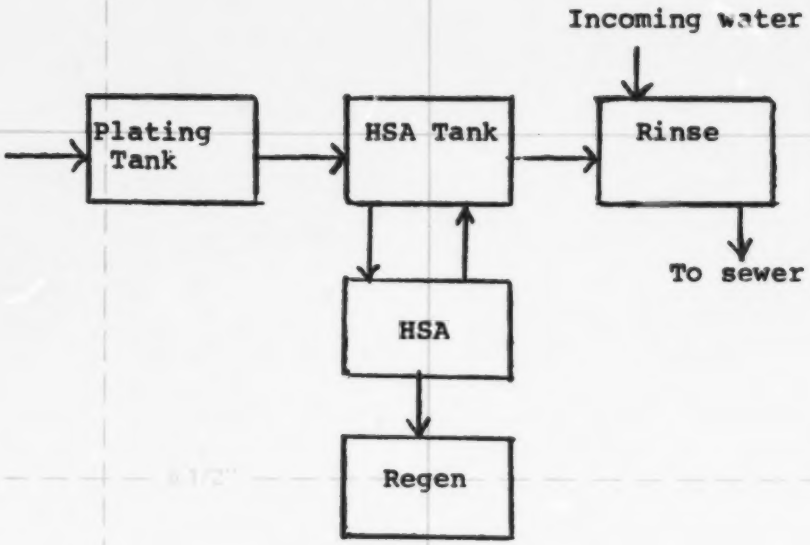


Figure 7. Process Flow Diagram for Site 5

3. The composite samples would be one cycle in duration. A cycle is defined as the time of HSA operation between regenerations.

4. An initial grab sample of the strip solution used to strip cadmium from the carbon cathodes followed by a grab sample of same after each cathode regeneration.

5. A total of two (2) cycles would be sampled over a week's (5 days) production.

The sampling plan was successfully executed with the exception of the following:

Site 5 owner, ordered new (never before used) carbon cathodes installed in the HSA unit for the second cycle due to an abundance of carbonate buildup on the usual second set of cathodes. When the operator attempted to install the cathodes into the strip unit, the panels were approximately 1/8" over- sized. The cathodes were then stripped overnight using a 5% HCl solution.

Actual operating schedule during sampling was as follows:

Day	HSA	Plating Line
1	7 hrs 55 min	8 hrs 00 min
2a First regeneration	5 hrs 20 min	5 hrs 20 min
2b	3 hrs 47 min	3 hrs 00 min
3	9 hrs 05 min	3 hrs 45 min
4a Second regeneration	7 hrs 25 min	7 hrs 25 min

Notes: 1 begin cycle one
21 end cycle one - cathode change
2b begin cycle two
4a end cycle two - cathode change

Regeneration schedule:

First regeneration: Day 3
Regeneration accomplished via MER unit in normal operation.

Second regeneration: Day 5
Regeneration accomplished via acid strip. See explanation below.

General Operation and Maintenance of the HSA System

- Regeneration of cathodes is considered time consuming by the owner

- o Lack of instrumentation to return real time operating/efficiency data is considered a shortcoming.

  o Cathodes are considered fragile and replacement is expensive.

- o The system is thought to require a moderate amount of manpower to operate and maintain.

- o Plant personnel stated that operation of the HSA could be more clearly defined in an operations manual.

TABLE 13..PERFORMANCE AT SITE 5

	CADMIUM, MG/L			CYANIDE, MG/L			Cd, MG/L
Run	DiDo	Rinse	HSA Tank	DiDo	Rinse	HSA Tank	Regen.
1		4,560	3,200		26,000	20,000	
						before	28,000(1)
						after	129,000
2		7,400	1,240		36,000	28,000	
						before	4,200(2)
						after	24,400

(1) regenerated in HSA system
(2) regenerated in acid strip

TABLE 14..DATA SHEET FOR SITE 5

PLANT DATA

PLANT OPERATION:	16 HRS/DAY
PLATING LINE OPERATION	9-1/2 HRS/DAY

HSA DATA

HSA OPERATION	Same as plating line operation
METAL RECOVERED:	Cadmium
MODEL NO:	MRS201, MCN201, MCS201
SIZE:	4 element
DRAGOUT SOURCE:	drag/in-drag/out rinse
PLATING LINES SERVICED:	1-manual barrel line
REGENERATION FREQUENCY:	once per week
STRIPPING METHOD:	reverse current
RECTIFIER SETTINGS:	2.9-3.0 volts
	500-650 amps

SITE 6

Description

Site 6 is a medium size job shop operating in southwest Toronto. Plating operations observed during the visit include cadmium, zinc, and tin along with various surface coatings. Operations include manual barrel and automatic barrel plating lines. The facility provides quick turnaround of large quantities of small hard to plate materials for the transportation industry, and electrical industry as well as an assortment of non-related local industries. The HSA system was installed to destroy cyanide in order to better enable Site 6 to comply with the local municipal effluent regualtions.

Plating Operation

One manually operated cadmium barrel plating line is connected to the HSA system at Site 6. Platers on pass material through the HSA tank only when plating cadmium. There is no rinse tank between the plating tank and the HSA rinse tank.

HSA System

Site 6 operates a four element metal removal system (MRS401-4), and a four element cyanide destruct system (MCS401-4). The cathode elements in the metal removal system are stripped by oxygen whereby the cadmium is returned to a strip solution similar in composition to a plating bath solution.

During the initial contact, plant personnel stated that the plating line, when at full production, normally operated 24 hours per day. Regeneration was done every 2 - 3 days.

Site 6 operated their metal removal rectifier at 5 volts and 250 amps. The rectifier supplying power for the cyanide destruct was not observed.

HSA Tests

Site 6 plates a wide range of geometrically shaped material. During the sampling period, the line changed material between 5 and 20 times per day. Maximum number of barrels plated were 74 per day and minimum number was 52 per day.

The original sampling strategy was designed to characterize the cadmium and cyanide removal capabilities of the HSA. The specific design is as follows:

1. Composite sample of the plating tank.

2. Composite sample of the rinse connected to the HSA unit (after the plating tank).

3. The composite samples would be one cycle in duration. A cycle is defined as the time of HSA operation between regenerations.

4. An initial grab sample of regenerant solution used to strip cadmium from the cathodes followed by a grab sample of same after each cathode regeneration.

5. A total of three (3) cycles would be sampled over a week's (5 days) production.

The sampling plan was successfully executed with the exception of the fact that Site 6 uses an oxygen strip without using electrical current. This results in a regeneration time approximately equal to the recovery operation time. Site 6 owns only one set of four (4) cathodes. Therefore, even though the plating line operates 24 hrs per day, the HSA system operated in the recovery mode only 50% of the production time. Consequently less cycles (2) were observed and sampled.

Actual operating schedule during sampling was as follows:

HSA recovery mode	1400 hrs on day 1 to 0900 hrs on day 2
First regeneration	0900 hrs on day 2 to 1250 hrs on day 3
HSA recovery mode	1250 hrs on day 3 to 1005 hrs on day 4
Second regeneration	1005 hrs on day 4 to 1030 hrs on day 5

Site 6 operates the HSA on a twenty-four (24) hours per day basis. The recovery system is shut down for regeneration (since there is only one set of available cathodes).

General Operation and Maintenance of the HSA Systems

- Regeneration of cathodes - Site 6 operates the HSA in the metal removal mode approximately 50% of the production time, the other 50% is regeneration.

- This unit is one of 2 pretreatment systems operating prior to final treatment. The other unit, based upon a different reactor design, is used for zinc recovery.

- Plant personnel stated that Site 6 has owned an HSA system for many years. The system presently operating is less than 2 years old. Site 6 was originally one of the earliest users of the HSA system.

TABLE 15. PERFORMANCE AT SITE 6

	CADMIUM, MG/L		CYANIDE, MG/L		Cd, MG/L
Run	Plating tank	HSA Tank	Plating tank	HSA Tank	Regen.
					54,211
1	29,729	902	60,426	8,772	67,870
2	17,954	3,468	59,328	25,276	95,073

TABLE 16. DATA SHEET FOR SITE 6

PLANT DATA	
PLANT OPERATION:	24 HRS/DAY
PLATING LINE OPERATION	24 HRS/DAY
HSA DATA	
HSA OPERATION	24 HRS/DAY
METAL RECOVERED:	Cadmium
MODEL NO:	MRS401-4, MCS401-4
SIZE:	4 element
DRAGOUT SOURCE:	Plating tank
PLATING LINES SERVICED:	1 - mamual barrel line
REGENERATION FREQUENCY:	2 - 3 times per week
STRIPPING METHOD:	reverse current with oxygen into solution
RECTIFIER SETTINGS:	5 volts
	250 amps